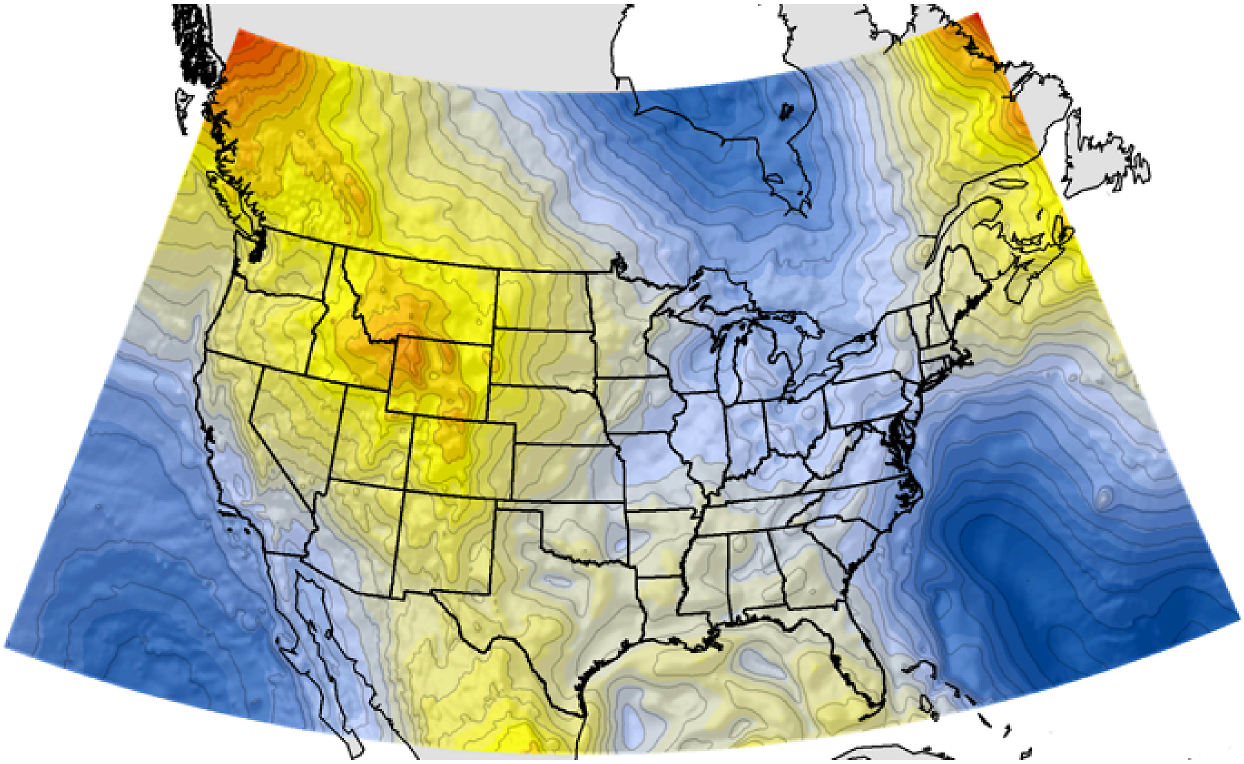
USGG2012



USGG2012 is a refined gravimetric model of the geoid in the United States and other territories, which supersedes the previous models USGG2009 and USGG2003.

For USGG2012 in CONUS regions, heights range from a low of -52.53 meters (magenta) in the Atlantic Ocean to a high of 3.47 meters (red) in the Labrador Strait.

USGG2012 refers to a GRS 80 ellipsoid, centered in the IGS08 (2005.00) reference frame, and is the best geopotential surface that approximates Mean Sea Level (MSL).

USGG2012 is NOT for converting between NAD83 and NAVD88.

USGG2012 is suitable for use with WGS84 and scientific applications.

Technical Details

Introduction

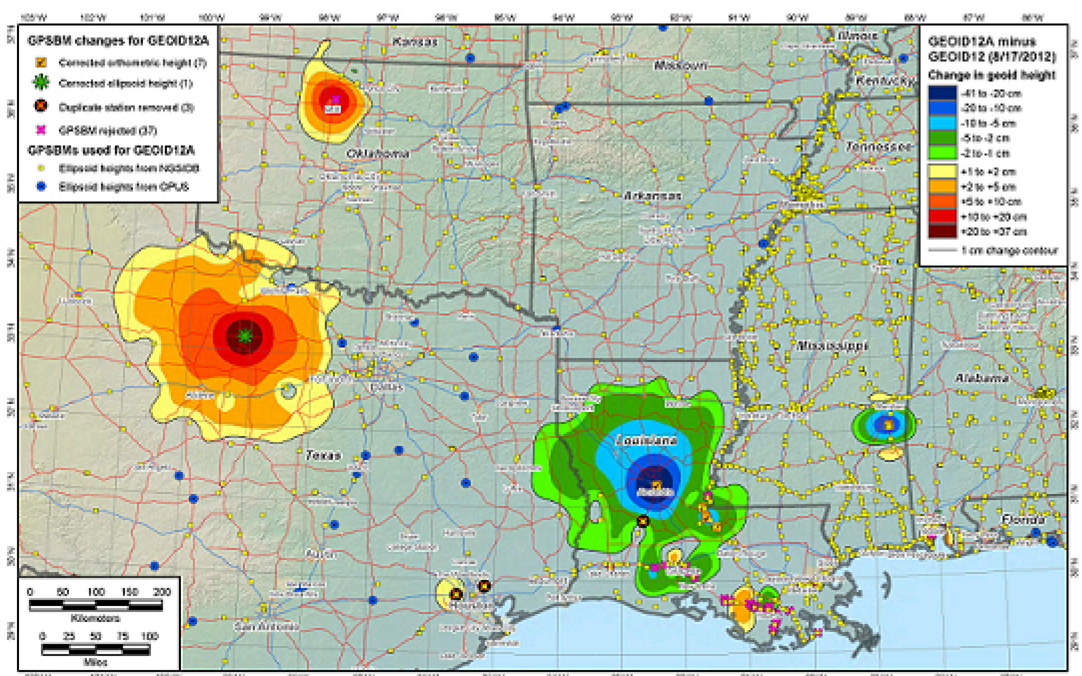
The National Geodetic Survey (NGS) has been producing the hybrid geoid to covert the ellipsoidal height obtained from the Global Navigation Satellite System (GNSS) to the orthometric height of a specific vertical datum. The following vertical datums are available for the United States territory: **North American Vertical Datum of 1988** (NAVD 88) for the conterminous United States, the **American Samoa Vertical Datum of 2002** (ASVD02), the **Guam Vertical Datum of 2004** (GUVD04), the **Northern Marianas Vertical Datum of 2003** (NMVD03), and the **Puerto Rico Vertical Datum of 2002** (PRVD02). The hybrid geoid models have been used as zero height surfaces for these datums. Since the GPS bench marks (GPSBM) have been collected and the ellipsoidal height has been adjusted, the hybrid geoid will continue to be updated until NGS releases a new gravimetric geoid-based vertical datum in 2022.

Why are there GEOID12/12A/12B models?

There are different models, because there are slight differences in the GPSBM data used for each model. However, these differences are limited to a few areas, mainly in southern tier states along the Gulf Coast and Puerto Rico.

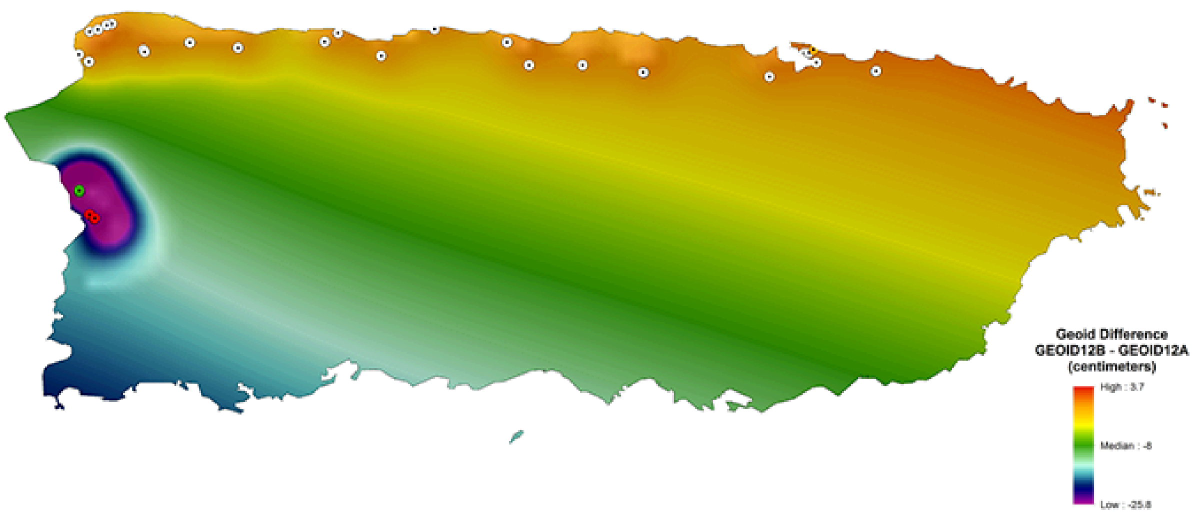
GEOID12 is created using the GPSBM data of the **National Adjustment of 2011.** The median change in coordinates from previously published values was approximately 2 centimeters horizontally and 1.5 centimeters vertically. However, some station coordinates changed by more than 1 meter horizontally and 60 centimeters vertically.

GEOID12A uses the same GPSBM data as GEOID12, excluding the points in southern tier states along the Gulf Coast. See the map below for details.



Changes from GEOID12 to GEOID12A

GEOID12B is identical to GEOID12A, except in Puerto Rico. Some discrepancies with respect to PRVD02 were found due to a few GPSBMs that referred to local mean sea level rather than PRVD02. The problem was identified and corrected. A map of the changes is shown below.



Changes from GEOID12A to GEOID12B

What is the effect of the gravimetric geoid USGG2012?

All three GEOID models are computed based on the gravimetric geoid USGG2012 . More specifically, they are computed using the satellite model GOCO3S, terrestrial gravity data, and the altimetric gravity anomaly over oceans. The heights of USGG2012 represent an equi potential surface relative to the reference ellipsoid. The differences between USGG2012 and the zero height surface of NAVD88 are represented by GPSBM data.

Currently, the USGG2012 is fitted to the GPSBM data by using the method of least squares collocation. That implies that the voids or empty areas where there are no GPSBM data are filled in by USGG2012 geoid.

How are hybrid geoid models generated?

There are over 500,000 leveled marks and 80,000 GPS marks over U.S. territory. Of those, there are only 26,000 GPSBM, with half of them concentrated in 5 states. The data density is uneven and sparse in some states. Lists of GPSBMs can be downloaded from the GEOID12B home page.

The GPSBM data provide the geoid height ‘N’ by differencing the ellipsoidal height ‘h’ from the orthometric height ‘H’:

$N = h - H$

The difference between the geoid height N and that of USGG2012 is computed at every GPSBM. Then, a mathematical model using Least Squares Collocation (LSC) fitting Gaussian functions to describe the behavior seen at the GPSBM is developed. Figure 1 shows empirical data versus the model.

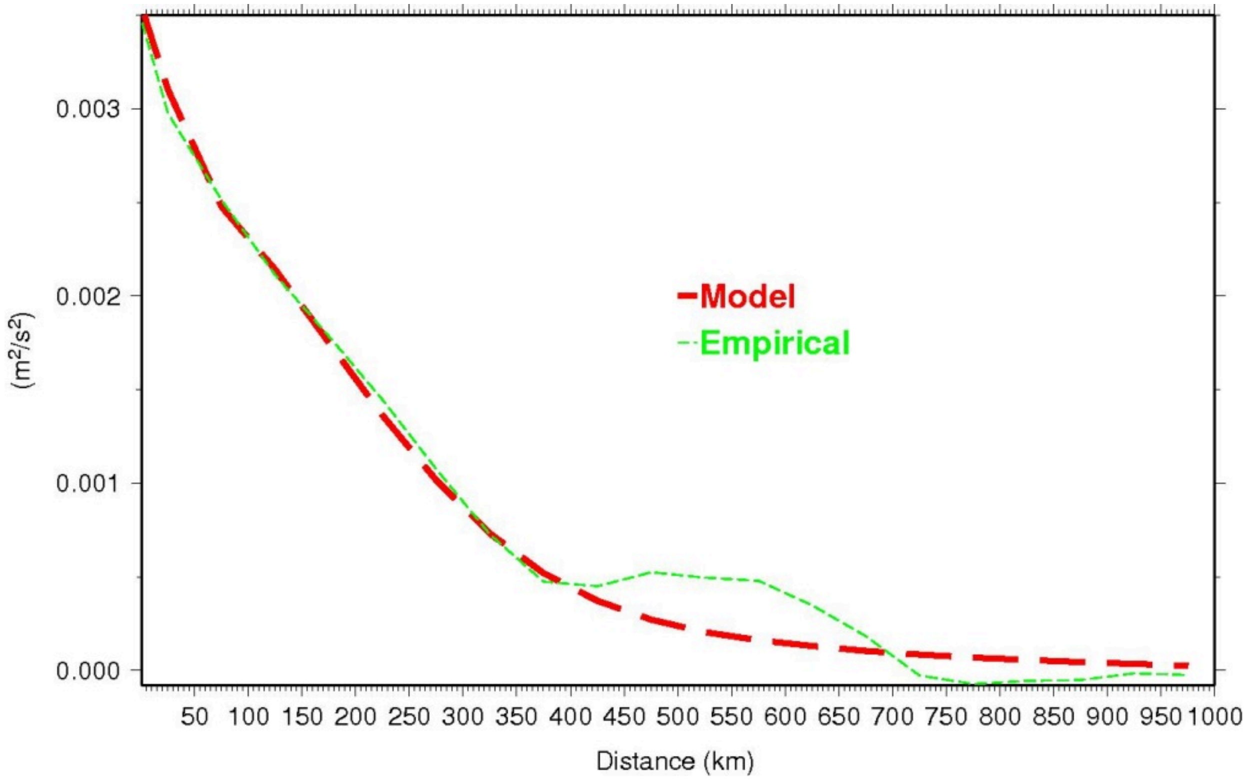


Figure 1: Covariance functions of the geoid differences between USGG2012 and GPSBMs

Once the relationship between the points is modeled, the model is used to generate a regular grid for interpolation purposes. Figure 2 shows the final conversion surface. This surface represents the difference between NAVD 88 as a datum and the geopotential (geoid) surface used in the gravimetric geoid and is representative of what the datum transformation surface will be when the new geopotential datum is released in 2022.
(Similar to VERTCON, which transforms heights from NGVD29 to NAVD88)

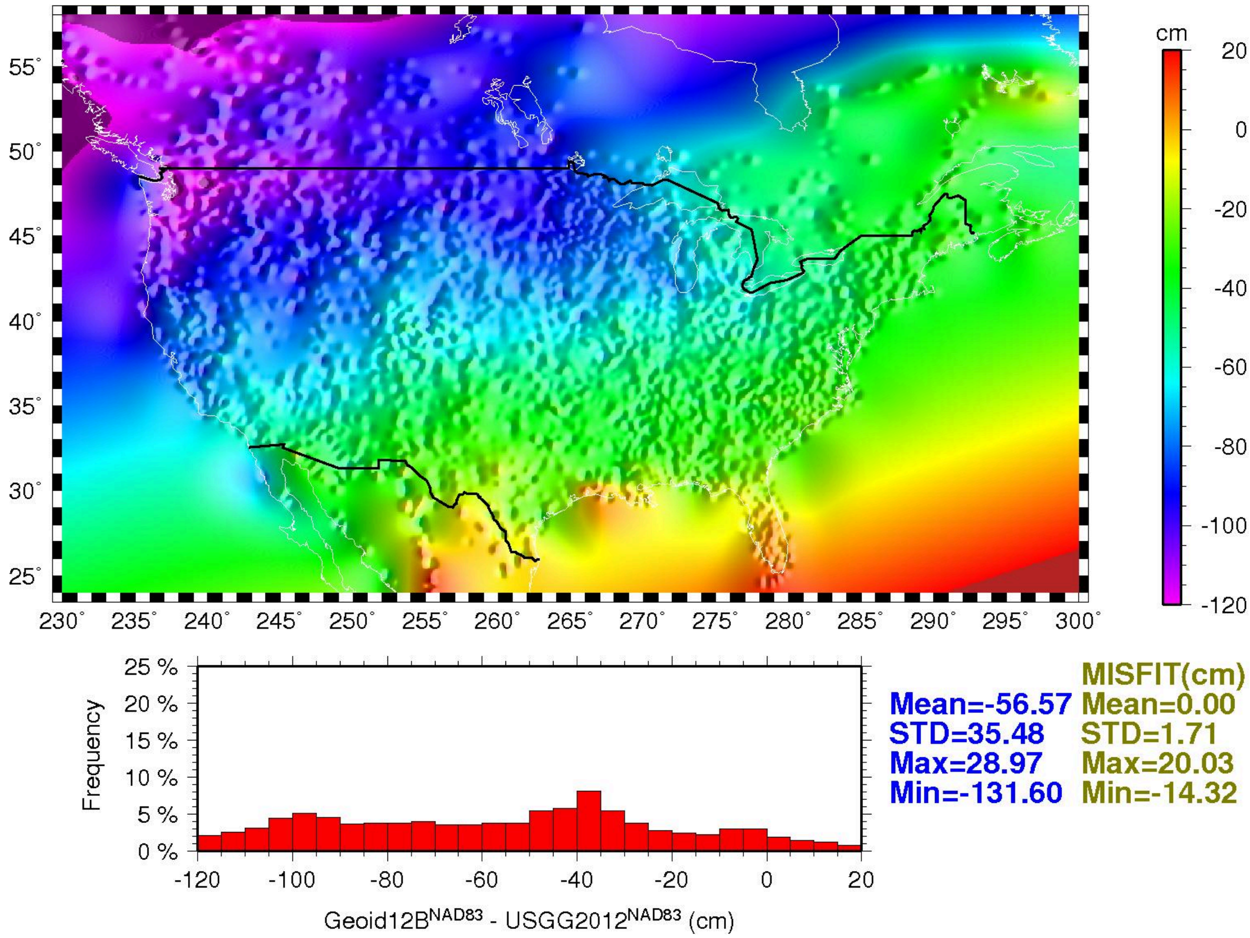


Figure 2: GEOID12B conversion surface

What other models are publicly available?

Gravimetric geoids

USGG2012 covers the entire area of the United States and its territories. On an annual basis, experimental geoid models will also be developed using the best gravity data available. For more information, visit **xGEOID14 Web pages.**

Hybrid geoids

GEOID12, GEOID12A, and GEOID12B models cover the United States and its territories, with the exception of Hawaii where there is no official vertical datum.

Hybrid geoid accuracy: The accuracy files for GEOID12B cover the United States and its territories, with the exception of Hawaii.

Deflections of the vertical (DoV) can be computed from the gravimetric and hybrid geoid models. The DoV computed from the gravimetric geoid is designated as USDOV2012; and the version computed from the hybrid geoid is designated as DEFLEC12B.

Summary and Recommendations

Three hybrid geoid models GEOID12, GEOID12A, and GEOID12B are created. They are very similar, but have distinctive differences in few areas. GEOID12A differs from GEOID12 usingin that it does not use GPSBM data collected in the southern tier states along Gulf Coast, while GEOID12B differs from GEOID12A only in Puerto Rico.

Data in the database are constantly updated, hence older geoid models do not reflect the newer data. To guarantee data consistency, latest model should be used. At this time, GEOID12 and GEOID12A should be superseded by GEOID12B.

Use data conversion outside the GPSBM data areas with caution. Significant extrapolation errors are expected in areas where there are no GPSBM data.

The relative accuracy of GEOID12B to NAVD88 is characterized by a misfit of +/-1.7 centimeters nationwide.

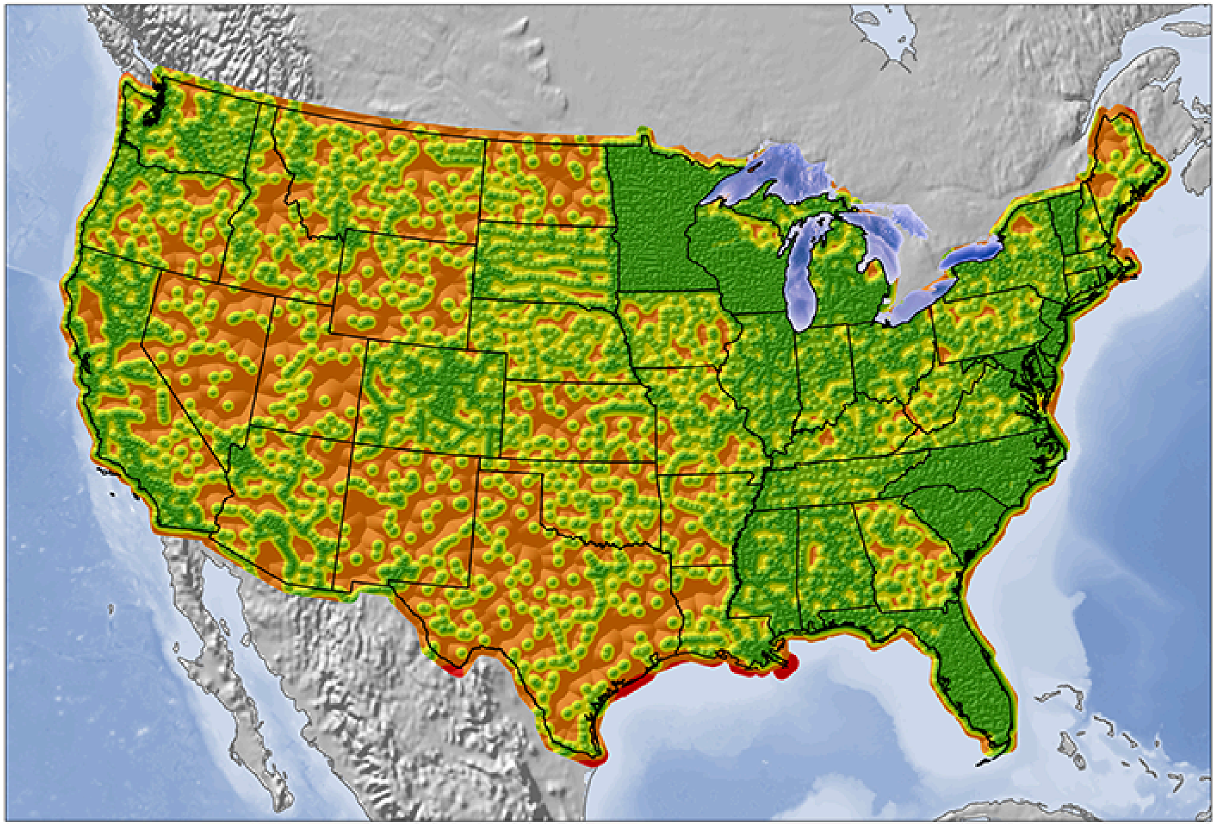
Frequently Asked Questions for USGG2012/GEOID12B/USDOV2012/DEFLEC12B

Question: What is the difference between GEOID12A and GEOID12B?

Answer: GEOID12B is identical to GEOID12A everywhere, except in Puerto Rico and Virgin island region.

Question: What does the national accuracy map for GEOID2B look like?

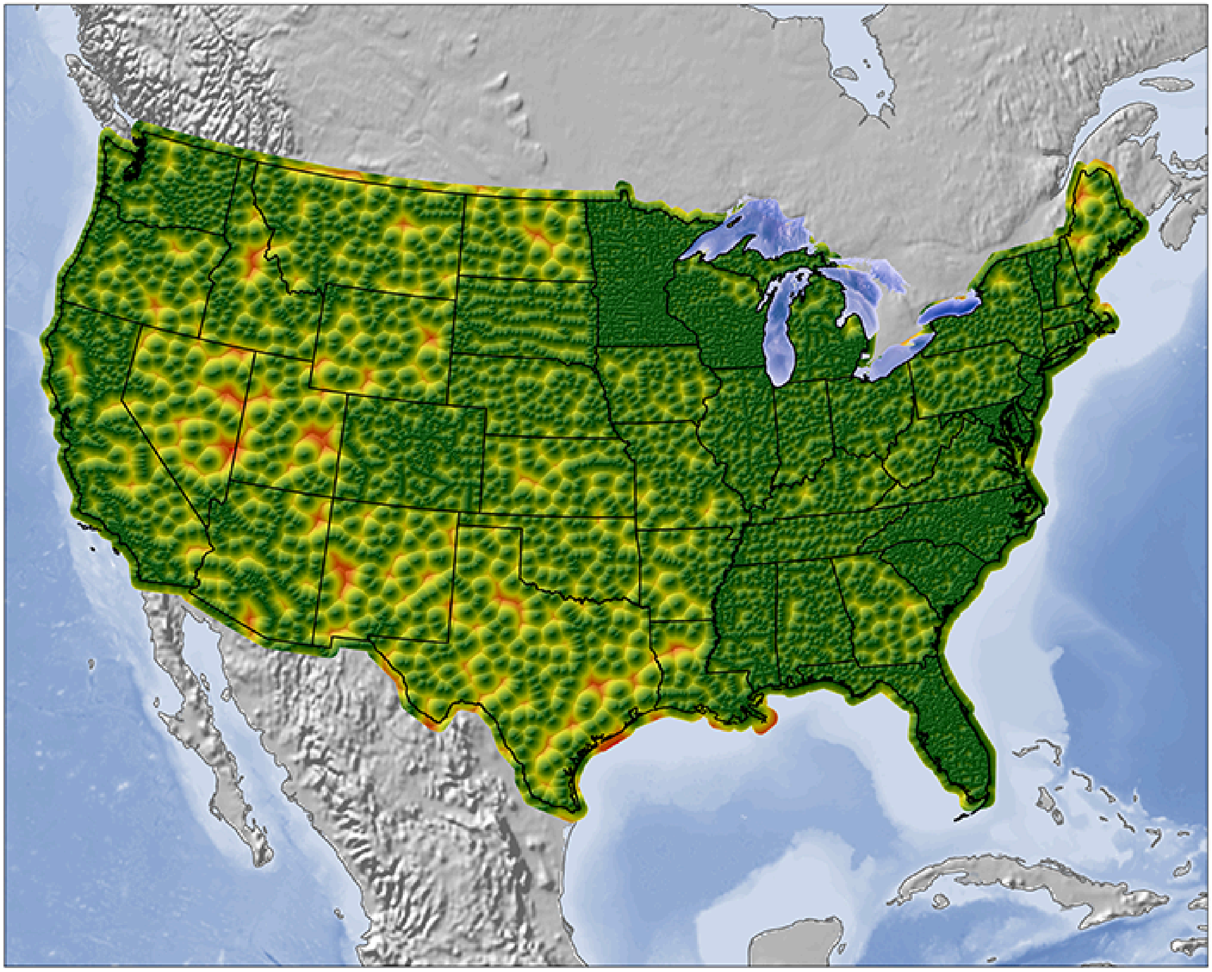
Answer: Here is the map for the Accuracy of GEOID12B for the Conterminous United States (lower 48).
Click the image for a larger map.



Question: What does the national map of the distance to nearest bench marks used in GEOID2A look like?

Answer: Here is the map for the distance to nearest bench marks used in GEOID12B for the Conterminous United States (lower 48).

Click the image for a larger map.



Question: What can I find the state-by-state statistics, such as those that were provided for GEOID12B?

Answer: The statistics are in the tables below

Conterminous United States

State	# pts	Mean	STD	Max	Min
AL	390	0	0.019	0.141	-0.107
AR	144	0.001	0.019	0.063	-0.046
AZ	337	0	0.023	0.092	-0.087
CA	793	0	0.023	0.098	-0.081
CO	602	0	0.028	0.112	-0.094

CT	24	0	0.015	0.021	-0.038
DC	17	-0.007	0.027	0.024	-0.091
DE	68	0	0.015	0.034	-0.046
FL	2523	0	0.018	0.2	-0.143
GA	150	0	0.018	0.06	-0.053
IA	103	-0.001	0.014	0.056	-0.046
ID	137	0.001	0.018	0.058	-0.061
IL	420	0.001	0.014	0.059	-0.084
IN	133	0	0.017	0.04	-0.095
KS	117	0	0.017	0.056	-0.066
KY	184	-0.002	0.015	0.048	-0.077
LA	149	0	0.03	0.108	-0.091
MA	43	0	0.017	0.049	-0.038
MD	557	0	0.02	0.089	-0.096
ME	69	0	0.015	0.045	-0.042
MI	807	0	0.017	0.088	-0.078
MN	7086	0	0.011	0.063	-0.101
MO	193	0	0.018	0.069	-0.072
MS	466	0	0.021	0.109	-0.103
MT	225	0	0.018	0.066	-0.067
NC	1987	0	0.017	0.08	-0.109
ND	63	0.002	0.016	0.085	-0.041
NE	158	0	0.014	0.084	-0.059
NH	24	-0.002	0.014	0.035	-0.021
NJ	383	0	0.015	0.057	-0.095

NM	130	0	0.022	0.075	-0.087
NV	72	0.001	0.016	0.038	-0.032
NY	252	0	0.014	0.061	-0.042
OH	312	0	0.026	0.094	-0.08
OK	82	0	0.017	0.041	-0.099
OR	244	0.001	0.022	0.099	-0.07
PA	121	-0.001	0.018	0.082	-0.059
RI	33	0	0.024	0.087	-0.039
SC	1536	0	0.016	0.093	-0.098
SD	250	0	0.013	0.084	-0.043
TN	313	0	0.02	0.088	-0.051
TX	259	0	0.02	0.096	-0.104
UT	58	0	0.016	0.049	-0.031
VA	478	0	0.02	0.098	-0.088
VT	449	0	0.016	0.08	-0.07
WA	324	-0.001	0.022	0.072	-0.131
WI	992	0	0.01	0.077	-0.088
WV	61	0.002	0.021	0.079	-0.052
WY	115	0	0.026	0.096	-0.069
Total	24433	0	0.017	0.2	-0.143

Outside Conterminous United States

State / Territory	# pts	Mean	STD	Max	Min
AK	200	0	0.03	0.236	-0.25

GU	33	0	0.025	0.038	-0.063
NM	55	-0.002	0.16	0.35	-0.32
AS	21	0.001	0.026	0.058	-0.054
PR	37	0	0.06	0.135	-0.287
VI	21	0.001	0.022	0.035	-0.044
CD *	576	-0.002	0.017	0.06	-0.099
MX *	177	0	0.043	0.099	-0.108

Q: Why does NGS produce the new geoid models?

A: Survey monuments do not necessarily physically change, but their location coordinates may change, and this can happen for several reasons. Coordinates may change due to natural causes, such as tectonic plate shift as in areas of the western United States or Alaska, sediment deposition and consolidation as in southern Louisiana, or glacial rebound as in the Great Lakes region. They also may change due to physical changes by human factors, such as extraction of minerals as in areas around Houston Texas, or extraction of water as in southern Arizona.

While land masses (which contain physical survey monuments) may change, it is the National Geodetic Survey?s (NGS) task to report location coordinates relative to consistent physical models.

NGS? goal for a geoid model is to have it be consistent with actual physical characteristics as determined from current observations. Older geoid models, such as GEOID99 and GEOID03, were built using observation data from the time they were developed, but they are no longer considered to be consistent with the physical Earth.

Hence, we periodically produce new geoid models to reflect the changes in both types of heights (orthometric heights are also periodically updated), as well as to include new observations.

Q: What is the format for the data files?

A: The NGS .bin file format for any sub-grid file is identical: A 44-byte header followed by “nla” rows of data, each row being “nlo” elements long, each element being a 4-byte floating point number. The format chosen is known in FORTRAN language as “direct access binary.” The exact ordering of the bytes is mapped below:

```
  Bytes    Data    Variable   Variable
           Type    Name       Description
First Record:
   1- 8    real*8  glamn      Southermost Latitude  of grid (decimal degrees)
   9-16    real*8  glomn      Westernmost Longitude of grid (decimal degrees)
  17-24    real*8  dla        Latitude spacing  of grid     (decimal degrees)
  25-32    real*8  dlo        Longitude spacing of grid     (decimal degrees)
  33-36    int*4   nla        Number of rows    of grid
  37-40    int*4   nlo        Number of columns of grid
  41-44    int*4   ikind      Set to "1", meaning the gridded data is "real*4"

Subsequent Records:
```

```
   1- 4    real*4  data(1,1)  Gridded value at element 1,1 (Southwest corner)
   . . .

The rest of the file continues as 4 byte real values, filling in first the
south row (data(1,nlo) being the last variable in the south row), and then
proceeding northward.

The total number of bytes in a "*.bin" file is:
44 + 4*nla*nlo
```

Current models have dla and dlo equal to 1 arc-minute (0.01666666 degrees).

The data following the header record, as described above, row-major. Hence, each data record is a list of values “nlo” long (equating to the longitudinal intervals along the row of latitude) and the record length = “nlo” * 4 bytes

Then the next northern row of data will be listed. This continues until the northernmost row, which is at the bottom of the file.

Hence, the first value in the data is the SW corner of the grid (westernmost point of southernmost row), while the last point is in the NE corner (easternmost value on the northernmost row).

The binary data format is direct access. This means that the usual head/footer word that FORTRAN appends has been stripped off (just extra baggage). This is more akin to what C or other languages would read.

Inspect the XNTG_V12.ZIP files, available from various the GEOID12B and USGG2012 download pages. This program is designed to read a binary format input file and write an ASCII format output file.

Q: Which models do I use for which regions?

A: The names “USGG2012” and “GEOID12B” have been reserved for each region now covered, including the conterminous United States (CONUS), Alaska, Hawaii, Guam and the Commonwealth of the Northern Marianas Islands (CNMI), American Samoa, and Puerto Rico and the U.S. Virgin Islands (PRVI). All the gravimetric geoid models (USGG2012) are based on a GRS-80 ellipsoid shell in the IGS08 reference frame and a geopotential surface (W0) of 62,636,856.00 m**2/s**2. These models collectively define the same geopotential surface (geoid) determined from the underlying reference global earth gravity model (EGM2008). Hence, comparisons of these heights between different regions provide consistent values.

However, most people are interested in the hybrid geoid height models (GEOID12B). A hybrid geoid model can transform between a NAD 83 ellipsoid height and the relevant vertical datum for each region. For CONUS and Alaska, a hybrid geoid model can transform from a NAD 83 ellipsoid height to a NAVD 88 orthometric height. For Puerto Rico, the model can yield a PRVD02 elevation. Each region has its own vertical datum with the exception Hawaii. Heights in Hawaii refer to NAD 83 but also to the same geoid surface (W0) defined by the gravimetric geoid. The particular “flavor” of NAD 83 is also used for each region (i.e., NAD 83 [PA11] for Hawaii and American Samoa).

So use the hybrid geoid for each region to transform between NAD 83 and the relevant vertical datum.

The particular “flavor” of NAD 83 is also used for each region (i.e., NAD 83 [PA11] for Hawaii and American Samoa).

Area	Ellipsoid Reference Frame	Vertical Datum	Latitude	Longitude

			Min	Max	Min	Max
Conterminous US	NAD83 (2011)	NAVD88	24N	58N	60W	130W
Alaska	NAD83 (2011)	NAVD88	49N	72N	126W	188W
Hawaii	NAD83 (PA11)	See Note Below	18N	24N	154W	161W
Guam and Northern Mariana Islands	NAD83 (MA11)	GUVD04/NMVD03	11N	18N	143E	146E
American Samoa	NAD83 (PA11)	ASVD02	17S	11S	186E	192E
Puerto Rico / U.S. Vigin Islands	NAD83 (2011)	PRVD02 and VIVD09	15N	21N	64W	69W

NAVD88 – North American Vertical Datum of 1988

ASVD02 – American Samoa Vertical Datum of 2002

GUVD04 – Guam Vertical Datum of 2004

NMVD03 – Northern Marianas Vertical Datum of 2003

PRVD02 – Puerto Rico Vertical Datum of 2002

VIVD09 – Virgin Islands Vertical Datum of 2009 (pending)

Note: The vertical datum surface in Hawaii is identical to USGG2012, which is offset by 50-60 centimeters from some local tidal bench mark values.

Q: What is the major difference between GEOID09 and GEOID12B?

A: Both GEOID09 and GEOID12B determine the respective vertical datum surface for each region (e.g., NAVD 88 for CONUS). The differences arise from the underlying gravimetric geoids (USGG2009 and USGG2012, respectively) and control data sets (GPSBM2012 and OPUSDBBM12) available at the time of generation.

Both USGG2009 and USGG2012 were based on the EGM2008 reference model. However, the GOCO02S signal was incorporated into the reference model in 2012, and the Residual Terrain Model signal¬from 3 arcseconds through 5 arcminutes was accounted for in 2012 and not in 2009. Hence, USGG2012 has better and more consistent terrain models affecting the shortest wavelengths of the gravity field. The expectation is that USGG2012 is significantly more accurate than USGG2009.

Why is this important? Because the gravimetric geoid determines most of the actual features in the hybrid geoids. GPS-derived ellipsoid heights on leveled bench marks (GPSBM's) give the separation between NAD 83 and NAVD 88 at discrete points. These differences can be used to develop a conversion surface that effectively warps the gravimetric geoid surface to fit the GPSBM points. The resulting hybrid geoid then fits at the discrete GPSBM points, while still honoring the shorter wavelength features determined by the gravimetric geoid model in between the GPSBM's. Hence, the GPSBM's are also fairly important. GPSBM's continue to change; their values are not static. There are regions where the ground changes constantly, but most "changes" in height at the bench mark locations are due to a different height realizations. An adjustment is performed using different parameters, and a new value is determined for a height at a given location. The actual position of the height didn't change, only our understanding of where it is located has changed.

Since 2009, NGS performed the National Adjustment of 2011 (NA2011). NA2011 significantly affected the ellipsoid heights of data throughout the country. Since the GPSBM's are determined from the difference between the ellipsoidal (NAD 83) and orthometric (NAVD 88) heights, a change in one height type changes the control value and thus affects the hybrid geoid.

GEOID09 fit to the data available in 2009. If you are still using data from 2009, GEOID09 will fit better. However, NGS has changed the heights in the database for many of these points. GEOID09 will no longer fit the current values to (in some cases) better than the dm-level. GEOID12B was developed using current values, so GEOID12B should now be used if you want results consistent with those on the NGS datasheets (our current best estimate of actual heights), as well as OPUS solutions.

This brings up an additional point: While most data came from the NGS Integrated Database (and are listed as GPSBM2012), several hundred supplemental points were obtained from the OPUS Database (OPUSDBBM12), providing additional coverage in between the GPSBM2012 control data with decimeter-level impacts.

Both GEOID09 and GEOID12B yield estimates of NAVD 88. However, based on our current understanding of the true position of the coordinates, GEOID12B is a better fit. This, too, will change. As we develop better coordinates, the values in the database and those expressed on the datasheets will change. Consequently, GEOID12B will eventually become obsolete and will need to be replaced with an update that reflects the future database.

Q: If I know the geoid height model used to compute an orthometric height, how can I obtain an orthometric height based on a different geoid height model? For example, a height is determined using GEOID12B, but I want it based on GEOID09 instead.

A: Geoid height models are determined from the most current heights in the database. Sometimes it is beneficial to look at the value determined from an earlier model. To determine the orthometric height based on a new geoid height model, you would take the old value, add the old geoid height value, and subtract the new geoid height value:

Ortho height _(new geoid) = Ortho height _(old geoid) + Geoid height _(old geoid) – Geoid height _(new geoid)

GEOID12B README FILE

```
Original: November 25, 2014

The GEOID12B MODEL
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You have downloaded these files from the National Geodetic Survey?s (NGS) website.

Files you may have received include:

 INTG.EXE (PC) or   The geoid interpolation program
 INTG     (Solaris)  (source code is available)

 XNTG.EXE (PC) or   Program for extracting, translating (ASCII/binary)
 XNTG     (Solaris) and yielding statistics of geoid files
                     (source code is available)
```

Please be sure you have downloaded these programs from this page, as these are the most recent versions to read the GEOID12B and USGG2012 models; previous versions of INTG and XNTG may not read properly.

The following file names are valid for binary files. However, if you downloaded the ASCII versions of these files, the suffix will be ".asc," rather than ".bin"):

Grid Name	Model	Region Covered (latitude & both East/West longitude)
g2012Bu0.bin	GEOID12B	entire grid for CONUS (24-58N, 230-300E/130-60W)
g2012Bu1.bin	GEOID12B	grid #1 for CONUS (40-58N, 230-249E/130-111W)
g2012Bu2.bin	GEOID12B	grid #2 for CONUS (40-58N, 247-266E/113-94W)
g2012Bu3.bin	GEOID12B	grid #3 for CONUS (40-58N, 264-283E/96-77W)
g2012Bu4.bin	GEOID12B	grid #4 for CONUS (40-58N, 281-300E/79-60W)
g2012Bu5.bin	GEOID12B	grid #5 for CONUS (24-42N, 230-249E/130-111W)
g2012Bu6.bin	GEOID12B	grid #6 for CONUS (24-42N, 247-266E/113-94W)
g2012Bu7.bin	GEOID12B	grid #7 for CONUS (24-42N, 264-283E/96-77W)
g2012Bu8.bin	GEOID12B	grid #8 for CONUS (24-42N, 281-300E/79-60W)
g2012Ba0.bin	GEOID12B	entire grid for Alaska (60-72N, 172-204E/188-126W)
g2012Ba1.bin	GEOID12B	grid #1 for Alaska (60-72N, 172-204E/188-156W)
g2012Ba2.bin	GEOID12B	grid #2 for Alaska (60-72N, 202-234E/158-126W)
g2012Ba3.bin	GEOID12B	grid #3 for Alaska (49-61N, 172-204E/188-156W)
g2012Ba4.bin	GEOID12B	grid #4 for Alaska (49-61N, 202-234E/158-126W)
g2012Bh0.bin	GEOID12B	entire grid for Hawaii (18-24N, 199-206E/161-154W)
g2012Bg0.bin	GEOID12B	entire grid for Guam/CNMI (11-18N, 143-146E/217-214W)
g2012Bp0.bin	GEOID12B	entire grid for Puerto Rico and U.S. Virgin Islands (13-21N, 291-296E/69-64W)
g2012Bs0.bin	GEOID12B	entire grid for American Samoa (17-11S, 186-192E/174-168W)

To Install:

1) Make a subdirectory on your hard disk.
2) Copy the various geoid files into that subdirectory. You do not need to put the geoid files in the same directory as the INTG and XNTG programs, although you will need to specify the path. If you have also received USGG2012 or any other model files, you may safely place them in the same directory as GEOID12 should you wish to do so.

To Execute

(PC or Sun) Type INTG, then follow the prompts in a Command Prompt shell in Windows or a Unix terminal. This will ensure it doesn't close immediately after completion, and you will be able to examine the output statistics.

To Terminate

You can stop the program at any time using <Control> C.

File Structure

The files (ASCII and binary) follow the same structure of a one-line header followed by the data in row-major format. The one-line header contains four double (real*8) words followed by three long (int*4) words.
These parameters define the geographic extent of the area:

```
SLAT:  Southernmost North latitude in whole degrees.
       Use a minus sign (-) to indicate South latitudes.
WLON:  Westernmost East longitude in whole degrees.
DLAT:  Distance interval in latitude in whole degrees
       (point spacing in E-W direction)
DLON:  Distance interval in longitude in whole degrees
       (point spacing in N-S direction)
NLAT:  Number of rows
       (starts with SLAT and moves northward DLAT to next row)
NLON:  Number of columns
       (starts with WLON and moves eastward DLON to next column)
IKIND: Always equal to one (indicates data are real*4 and endian condition)
```

The data follows after this one-line header. The first row represents the southernmost row of data, with the first data point being in the SW corner. The row is NLON values wide spaced at DLAT intervals, and then increments to the next row which is DLAT to the north.
This continues until the last row where the last value represents the northeast corner.
The easternmost longitude is = WLON + (NLON - 1) * DLON, while the northernmost latitude is = SLAT + (NLAT - 1) * DLAT.

Check The Byte Counts of all Downloaded Files

Before beginning, it will be useful to ensure all files you have received are the correct size. (Download problems are often manifested by incorrect byte counts in the files). Check with the list below to make sure your files match these numbers exactly. These values are good for the PC and Sun versions of the data.

```
PC or Sun Data:
     g2012Bu0.bin   34,297,008 bytes
     g2012Bu*.bin    4,933,728 bytes
     g2012Ba0.bin   20,554,848 bytes
     g2012Ba*.bin    5,540,208 bytes
     g2012Bh0.bin      607,968 bytes
     g2012Bg0.bin      304,848 bytes
     g2012Bp0.bin      434,688 bytes
     g2012Bs0.bin      521,328 bytes
ASCII Data (uncompressed):
     g2012Bu0.asc   86,816,078 bytes
     g2012Bu*.asc   12,488,895 bytes
     g2012Ba0.asc   52,030,658 bytes
     g2012Ba*.asc   14,024,273 bytes
     g2012Bh0.asc    1,539,045 bytes
     g2012Bg0.asc      771,795 bytes
     g2012Bp0.asc    1,100,430 bytes
     g2012Bs0.asc    1,319,918 bytes
C Program Source Code:
```

```
     INTG_V317.ZIP     106,269 bytes
     XNTG_V12.ZIP       28,914 bytes
PC executables:
     INTG.EXE          122,331 bytes
     XNTG.EXE          127,414 bytes
Sun executables:
     INTG              186,500 bytes
     XNTG               95,212 bytes
```

How Program INTG Works

The various geoid height grids are stored in the ".bin" files. Program INTG will prompt you for the name of the directory where you have chosen to store the .bin files, as well as prompt you for the geoid model you wish to use. You can operate with as few as one .bin file, or you may use the entire geoid model data set. If a master file is given
(e.g., g2012Bu0.bin for CONUS), it should be used instead of the individual subgrids. When the program interpolates a given point, it checks an internal list of .bin boundaries and uses the earliest list entry whose boundaries contain the best data scheme to interpolate that point. The order of the .bin file names on the opening screen indicates the order in which the .bin files are searched. This particularly applies to where the CONUS and Alaska grids overlap.

When running program INTG.EXE (PC) or INTG (Sun), you must input the latitude and longitude of each point. The GEOID12B models are heights above the NAD 83 ellipsoid. While the latitudes and longitudes in the IGS08/GRS-80 and WGS84 systems are very close to those of the NAD 83 system (with only 1 to 2 meters of horizontal shift), NAD 83 (2011/PA11/MA11) coordinates should exclusively be used. If necessary, use HTDP (available in the NGS Tool Kit) to convert into the appropriate ellipsoidal datum (2011: for CONUS, AK, PR, VI; PA11 for HI and Am. Samoa; and MA2011 for Guam and CNMI).

GEOID12B geoid heights will always reference NAD 83, not IGS08/GRS-80.
USGG2012 geoid heights will always reference IGS08/GRS-80, not NAD 83.

Do *NOT* use NAD 27 latitudes and longitudes. The horizontal shifts between NAD 83 and NAD 27 can exceed 100 meters, causing a noticeable difference in the interpolated geoid value. To convert from NAD 27 to NAD 83 latitudes and longitudes you may use NGS? NADCON program, available from the NGS Tool Kit.

Data Input

You can key data by hand, point by point, or you can create an input file using a text editor. Several file formats are provided, including the NGS "Blue Book" format. These formats are detailed in a "Help" menu option which appears if you specify you would like to use an input file.

Data Output

Results may be collected into an output file. There is no default output file name. To maintain consistency, the format of the output file is linked to the format of the input file. If, however, you input your data by keyboard and ask for an output file, the format of that output file will be in the format known as "Free Format, Type 1".

The GEOID12B Model

The GEOID12B model is a hybrid geoid model, as it is modified from a gravimetric model to fit GPS ellipsoid heights on leveled bench marks. The GEOID12B model refers to a GRS80 type ellipsoid, centered at the NAD83 origin. It supports direct conversion between NAD83 GPS ellipsoidal heights and NAVD88, GUVD04, NMVD03, PRVD02, VIVD09, and ASVD03 orthometric heights. In Hawaii, note that there is no defined vertical datum. Hence, in Hawaii GEOID12B converts between NAD 83 (PA11) and the W0 surface used to define USGG2012 (62,636,856.00 m**2/s**2).

When comparing the USGG2012 model with GPS ellipsoidal heights in the IGS08 reference frame and leveling in the NAVD 88 datum, one can discern a systematic offset at a 50-centimeter level and a national trend of about 1.2 meters. It is likely this offset is inherent in the definition of NAVD 88, since this same trend is seen when compared to global geoid height models. Since the errors are long-wavelength, they can be modeled locally as a plane; usually at a 1 to 2 part-per-million level. (See GEOID12B Technical Details for further information on how GEOID12B was developed from the GPSBM2012 and OPUSDBBM12 Control Data).

Deriving Orthometric Heights from GPS

One key concern is deciding which orthometric height datum to use. NGVD 29 is not a sea-level datum, and the heights are not true orthometric heights. The NAVD 88 datum is selected to maintain reasonable conformance with existing height datums, and its Helmert heights are good approximations of true orthometric heights. And, while differential ellipsoidal heights obtained from GPS are precise, they are often expressed in the NAD 83 datum, which is not exactly geocentric.

This leads to a warning:

Do not expect the difference of a GPS ellipsoidal height at a bench mark vertical datum height and the associated GEOID12B height to exactly match. The modeling process allowed for random errors that could approach 10 centimeters. However, one can combine the precision of differential carrier phase GPS with the precision of GEOID12B height differences, to approach that of leveling.

Include at least one existing bench mark in your GPS survey (preferably many bench marks). The difference between the published elevation(s) and the height obtained from differencing your adopted GPS ellipsoidal height and the GEOID12B model could be considered a "local orthometric height datum correction." If you are surveying an extensive area (100+ kilometers), and you occupy numerous bench marks, you may detect a trend in the corrections of up to a one part-per-million level. This may be error in the GEOID12B model.

We do not currently consider geoid-corrected GPS orthometric heights as a substitute for geodetic leveling in meeting the Federal Geodetic Control Subcommittee (FGCS) standards for vertical control networks. Studies are underway, and many less stringent requirements can be satisfied by geoid modeling. Widespread success has been achieved with the preceding models.

The XNTG Utility Program

The XNTG program can perform various functions, none of which are required to use the INTG program. The functions of XNTG are the extraction of sub-grids from the provided geoid grids, the translation between ASCII and binary grids, and the reporting of basic statistics for geoid grids.